(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 0 531 104 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
13.08.1997 Bulletin 1997/33

(51) Int. Cl.[6]: **A23L 1/015**, A23L 1/32, A23J 3/04, A23J 3/12

(21) Application number: **92307950.3**

(22) Date of filing: **02.09.1992**

(54) Process for producing a lipoprotein-containing substance having a reduced lipid content

Verfahren zur Herstellung eines Lipoprotein-enthaltenden Stoffes mit reduziertem Lipidgehalt

Procédé de préparation d'une substance contenant une lipoprotéine présentant une teneur réduite en lipides

(84) Designated Contracting States:
DE ES FR GB IT NL

(30) Priority: **03.09.1991 JP 222710/91**
06.11.1991 JP 289837/91

(43) Date of publication of application:
10.03.1993 Bulletin 1993/10

(73) Proprietors:
- **SUMITOMO SEIKA CHEMICALS CO., LTD.**
  Kako-gun Hyogo-ken (JP)
- **OTSUKA FOODS CO., LTD.**
  Osaka-shi Osaka-fu (JP)
- **MITSUBISHI CORPORATION**
  Tokyo-To (JP)

(72) Inventors:
- **Isono, Yoshikazu**
  Otsu-shi, Shiga-ken (JP)
- **Fukumoto, Michiyo**
  Osaka-shi, Osaka-fu (JP)
- **Hariu, Hitoshi**
  Kyoto-shi, Kyoto-fu (JP)
- **Takahashi, Masakazu**
  Kakogawa-shi, Hyogo-ken (JP)

(74) Representative: **Coleiro, Raymond et al**
MEWBURN ELLIS
York House
23 Kingsway
London WC2B 6HP (GB)

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- **PATENT ABSTRACTS OF JAPAN vol. 016, no. 406 27 August 1992**
- **DATABASE WPIL Section Ch, Week 8922, Derwent Publications Ltd., London, GB; Class D, AN 89-162870**

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EP 0 531 104 B1

Printed by Rank Xerox (UK) Business Services
2.14.12/3.4

Description

The present invention relates to a process for producing a lipoprotein-containing substance having a reduced lipid content.

Treatment of lipid containing substances is addressed in EP-A-0493045, acknowledged under Art 54(3) EPC. This discloses a method of reducing the level of cholesterol in a foodstuff containing lipids including phospholipids and cholesterol. The foodstuff is treated with a hydrolytic enzyme, in particular a phospholipase, capable of hydrolysing specifically phospholipid ester bonds. Simultaneously with or subsequent to hydrolysis, the foodstuff is subjected to a cholesterol removal step, for example, biochemical treatment, e.g. with cholesterol oxidase or solvent extraction e.g. with supercritical CO_2. Enzyme catalysed reactions in general are disclosed in US-A-4925790, which discloses the use of a supercritical fluid, such as CO_2, O_2, N_2O and C_2H_6, as a solvent for such reactions. The reaction product as a whole can be removed by changing the pressure and/or temperature of the supercritical fluid. However, there is no reference to treatment of lipoprotein-containing substances.

Lipoproteins are one of the conjugated proteins occurring widely in nature and having a structure in which at least one protein and some lipids are conjugated with each other.

Typical examples of the food materials which have been widely used are milk and egg yolk. For example, most of the proteins and lipids in egg yolk are present in the form of a lipoprotein.

The proteins and lipids, both of which constitute a lipoprotein, are indispensable nutrients to humankind. There is, however, a great demand for food having a low lipid content, based on a tendency to intake an excess of lipids, and people have an increasing consciousness that the intake of particular lipid ingredients such as cholesterol should be controlled.

In particular, egg yolk is a kind of complete nutritious food because not only does it have a good taste and a high nutritive value but also it is rich both in various vitamins and iron content. In addition, the functions of egg yolk, such as emulsifiability and thermocoagulability, have been utilized in various forms in processed food. However, because egg yolk contains some lipids, particularly cholesterol, at a high concentration, the intake of egg yolk is often controlled not only to treat patients with hyperlipidemia but also, for normal healthy people, to keep their bodies in good health. It is, therefore, desirable to reduce the lipid content, particularly cholesterol content, in egg yolk without deteriorating its taste and functions.

On the other hand, much attention is now given to blood plasma of slaughtered animals which has not yet been utilized as a food material but could become a useful protein material in future. Of course, blood plasma of slaughtered animals also contains a great amount of lipoproteins and it is well known that they are associated with the control of lipid transport and the control of intracellular lipid metabolism. The lipid material contained in the lipoproteins is the primary causative substance for development of a peculiar odor. Therefore, the blood plasma of slaughtered animals cannot be expected to find applications as a food material until the lipid content therein is reduced.

A general process is known for removing lipids from lipoprotein-containing substances, in which extraction is conducted with an organic solvent such as ethanol, methanol and chloroform, or a mixture thereof. This process is only used as an analytical technique and no attempt has been made to utilize it on an industrial scale.

In addition, as means for removing lipids from egg yolk which is a typical example of the lipoprotein-containing substances, there have been proposed extraction with dimethylether (JP-B 60-9770) and extraction with supercritical carbon dioxide (JP-A-59-135847, JP-A-59-140299, JP-A-3-98541 and EP-A-0416561), both of which are removal techniques only applied to egg yolk in a dry state For the purpose of removing lipids, particularly cholesterol, from liquid egg yolk, there have been proposed a few methods utilizing the mixing of egg yolk with edible oil (US-A-3717474, US-A-4333959 and GB-2238456). Moreover, we have developed a process for removal by extraction of cholesterol from liquid egg yolk which is brought into contact with supercritical carbon dioxide; see JP-A-3-206867 and EP-A-0426425.

When using an organic solvent, many problems arise, such as a change in emulsifiability and thermocoagulability, caused by denaturation of proteins; deterioration of flavor and texture during eating; and residual solvent.

As described above, lipoproteins comprise at least one protein and some lipid ingredients conjugated therewith, and they have a stable structure in water; therefore, any technique using a raw material in a dry state has the disadvantages that the protein is denatured and the lipid ingredients are oxidized in the step of heating the raw material. Moreover, the structure of the lipoproteins is broken by removal of water, and therefore, functional characteristics, such as emulsifiability, which are inherent to lipoprotein-containing substances, deteriorate. Furthermore, the drying step requires a great amount of heat energy, which also makes this technique unfavorable from the economical point of view.

In the process for removing cholesterol by mixing liquid egg yolk with edible oil, much force is required for stirring and shearing, and it is necessary to use a great amount of edible oil as an extraction agent. For this reason, such a process finds no industrial application. Moreover, the lipids contained in the lipoprotein-containing substance may be replaced by the edible oil used as an extraction agent in the step of extraction, thereby making it substantially impossible to reduce the lipid content. Furthermore, the large force applied for stirring and shearing, as well as heat generated thereby, may deteriorate the functional characteristics of the lipoprotein-containing substance, similarly to the case of a technique using a raw material in a dry state. Thus, there has been much difficulty so far in the removal of lipids from a

lipoprotein-containing substance usually in a liquid state without causing many problems as described above, i.e., without causing any change in the properties of the substance and causing any deterioration of its functional characteristics.

We have previously found a process for removing cholesterol from liquid egg yolk under mild conditions, by utilizing the characteristics of a supercritical fluid and by employing a wetted wall column system in bringing the liquid egg yolk into contact with the supercritical fluid. However, this process requires much time for removal by extraction of cholesterol because lipoproteins have a stable structure as described above, and it cannot yet be said that this process is satisfactory for practical use.

In view of the above we conducted intensive investigations directed towards finding a process for removing lipids from lipoprotein-containing substances without causing the above problems, which is, therefore, favorable from an economical point of view. As a result, we have found that extraction with a sub- or supercritical fluid after treatment with proteolytic enzymes and/or lipolytic enzymes is useful for reducing the lipid content in lipoprotein-containing substances.

Thus, the present invention provides a process for producing a lipoprotein-containing substance having a reduced lipid content.

In particular, according to the present invention, there is provided a process for producing a lipoprotein-containing substance having a reduced lipid content, which comprises the steps of

(1) treating a lipoprotein-containing substance with at least one enzyme selected from proteolytic enzymes, lipases and lipoprotein lipases;
(2) thereafter, bringing the enzyme treated substance into contact with a sub- or supercritical fluid to extract lipid therefrom; and
(3) separating the extracted lipid from the fluid. The process may be used to treat a food whose raw material is a lipoprotein-containing substance so as to reduce its lipid content.

Preferred methods embodying the invention will now be described.

In general, the lipids to be removed from lipoproteins by the process of the present invention are mainly monoglycerides, diglycerides, triglycerides, fatty acids, cholesterol, and phospholipids.

The process of the present invention can be applied to any substance so long as this substance contains lipoproteins. Typical examples of the lipoprotein-containing substances are egg yolk obtained by cracking eggs (including liquid egg yolk), whole egg (including liquid whole egg), treated egg yolk and treated whole egg, to which sugars, salts and the like are added for the purpose of storage and modification, as well as blood plasma of slaughtered animals and milk.

In general, proteolytic enzymes are classified into various enzymes by their sources or activities, i.e., those derived from possible sources such as plants, microorganisms and animals, or those having endopeptidase or exopeptidase activity. The proteolytic enzymes to be used in the present invention are not particularly limited and may be those of any kind. Typical examples of the proteolytic enzymes are Protease A, Protease P, Protease N, Protease S, Newlase F, Papain W-40, Bromelain, Protease M (all manufactured by Amano Seiyaku Co., Ltd.), Ceremix, Alcalase, Neutrase (all manufactured by Novo-Nordisk A/S), Pantidase NP2, Protease YD-SS, Aroase AP-10 (all manufactured by Yakuruto Honsha Co., Ltd.), Sumizyme AP, Sumizyme RP, Sumizyme LP (all manufactured by Shin Nihon Kagaku Kogyo Co., Ltd.), Actinase AS (manufactured by Kaken Pharmaceutical Co., Ltd.), Protin-and Protin-A (both manufactured by Daiwa Kasei Co., Ltd.).

These enzymes may be used solely or in combination.

The amount of proteolytic enzyme to be used is appropriately determined depending mainly upon the kind and reaction conditions of the respective proteolytic enzymes. Although the amount of proteolytic enzyme to be used is not particularly limited it is preferred that this is such that the degree of solubilization in 0.22 M trichloroacetic acid (TCA) of proteins in the treated substance ranges from 1.5% to 80%, more preferably from 1.5% to 30%.

It is especially preferred to select a degree of solubilization within the range of about 0.01% to 10% by weight based on the total weight of proteins in the treated substance. When the degree of protein solubilization is lower than 1.5%, the removal of lipids cannot be attained with high efficiency. On the contrary, when the degree of solubilization is higher than 80%, although the objects of the present invention may be attained, deterioration of physical properties and qualities of the raw material occurs, which is not practical. The conditions of enzyme reaction are not particularly limited and may be those usually used for each of the above enzymes. In usual cases, suitable conditions are selected for the purpose of avoiding the thermal denaturation of proteins in the raw material, i.e., a temperature of not higher than 65°C, preferably from about 30° to 60°C, and a reaction time of from about 0.5 to 48 hours, preferably about 0.5 to 10 hours.

Lipolytic enzymes which can be used in a process of the invention are selected from lipases and lipoprotein lipases, all of which may be derived from any possible source.

It is preferred to select from these enzymes suitable lipolytic enzymes for lipid decomposition of lipoproteins in the raw material. Examples of the commercially available lipolytic enzymes are Lipase F, Lipase M, Lipoprotein Lipase, Lipase A, Lipase AY (all manufactured by Amano Seiyaku Co., Ltd.), Porcine Pancreas Lipase (manufactured by Sigma Chem-

ical Company), Lecitase, Palatase (both manufactured by Novo-Nordisk A/S), Lipase "Saiken" (manufactured by Yakuruto Honsha Co., Ltd.), Talipase (manufactured by Tanabe Seiyaku Co., Ltd.) and Lipoprotein Lipase (manufactured by Toyobo Co., Ltd.).

The action of lipolytic enzymes may be such that the decomposition ratio of triglycerides or in the treated substance is in the range of from 1% to 80%, preferably from 5% to 50%. If the decomposition ratio is lower than 1%, the efficiency of lipid removal becomes poor. The cases where it is higher than 80% are also not practical, because of a change in the physical properties, such as an increase in the viscosity of the treated substance. Similarly to the case of proteolytic enzymes, the amount and reaction conditions of lipolytic enzymes to be used are not particularly limited so long as the desired decomposition ratio can be obtained. In the process of the present invention, so long as the desired decomposition ratio can be obtained, commercially available immobilized enzymes (e.g., Lipozyme 3A manufactured by Novo-Nordisk A/S) may be used, or the above proteolytic enzymes or lipolytic enzymes may be immobilized on an appropriate support according to a conventional process (e.g., Agric. Biol. Chem., 44, 413 (1980); Biotechnol. Bioeng., 14, 1031 (1972); and Anal. Biochem., 55, 282 (1973)) for use as an immobilized enzyme.

In general, lipoproteins have a structure in which a core portion composed of triglycerides and cholesterol esters is covered with a layer composed of phospholipids and cholesterol in free form, and to the surface thereof several kinds of proteins are attached. Most of the proteins have, when they are allowed to form an α-helix, one face consisting almost only of polar amino acid residues and the other face consisting almost only of nonpolar amino acid residues. This amphipathic feature makes it possible to mediate between water and oil, both of which are not compatible with each other, in such a manner that the protein portion of the lipoprotein directs its nonpolar face to neutral lipids and its polar face to the polar portion of the phospholipid or to a water phase.

It is, therefore, believed that the proteolytic enzyme used in the present invention partially breaks the coat structure of the lipoprotein, while the lipolytic enzyme causes a slight change in its structure by decomposition of the triglycerides present inside, resulting in an unbalanced polarity of the lipoprotein, whereby the removal of lipids by extraction can readily be made without deteriorating the functional characteristics of the lipoprotein.

Although each of the proteolytic enzymes and lipolytic enzymes may be used alone, it is desired that the kind and reaction conditions of enzymes suitable for the raw material to be treated therewith are determined by an experiment, because a combination of both enzymes may provide an increase in the efficiency of lipid removal.

The sub- or supercritical fluid is defined as a fluid in a state near or above its critical point. For example, the critical temperature and pressure for some fluids are as follows: 9°C and 50 atm. for ethylene; 31°C and 73 atm. for carbon dioxide; 37°C and 71 atm. for nitrous oxide; and 97°C and 42 atm. for propane. In the process of the present invention, the removal of lipids by extraction is preferably conducted with such a fluid in a state near or above its critical point. The sub- or supercritical fluid has a density near that of liquids and a large diffusion coefficient near that of gaseous materials, and because of these characteristics, rapid and large-scale extraction of various compounds can be attained with high efficiency. Moreover, a slight change in the pressure and temperature can make it easy to separate the extracts from the fluid.

The fluid to be used in the process of the present invention may be of any kind, if it is in a sub- or supercritical state as described above. Most preferred is carbon dioxide because of its solubility for lipids, safety, bacteriostatic or bactericidal action, economical feature, and possibility of conducting extraction at relatively low temperatures.

For the purpose of increasing the efficiency of lipid removal by extraction or attaining the selective removal by extraction of the particular lipid ingredients, it is also possible to mix a co-solvent with the sub- or supercritical fluid. Examples of the co-solvents to be used for the purpose of increasing the efficiency of lipid removal by extraction are ethanol, methanol, acetone and hexane. The kind and mixing ratio of co-solvents in the sub- or supercritical fluid are not particularly limited. For example, in cases where a substance obtained by the process of the present invention is a food material, it is believed that ethanol is most preferred because of its high safety.

Examples of the co-solvent to be used for the purpose of attaining the selective removal of particular lipid ingredients such as cholesterol and fatty acids are oils such as vegetable oils and animal oils. Among these oils, it is particularly preferred to use palm kernel oil, coconut oil, or medium-chain fatty acid triglycerides prepared therefrom. These oils have a high solubility in the sub- or supercritical fluid, which makes possible the efficient removal by extraction of the particular lipid ingredients. Further, it is also possible to attain the selective removal by extraction of only the particular lipid ingredients, while controlling freely the total lipid content in the lipoprotein-containing substance used as the raw material. Here it should be noted that the co-solvent to be used for this purpose contains few of, preferably no amount of, the particular lipid ingredients to be selectively removed. An oil as the co-solvent may be used either by mixing it with a sub- or supercritical fluid, or by adding it to the lipoprotein-containing substance which has been treated with enzymes such as proteolytic enzymes and/or lipolytic enzymes, followed by extraction with a sub- or supercritical fluid. The kind and mixing ratio of oils to be used herein are not particularly limited but should be appropriately determined depending upon the kind of the raw material, the kind of the particular lipid ingredients to be selectively removed.

The purpose of the extraction step of the present invention can be attained by using a sub- or supercritical fluid at a pressure of from 50 to 500 kg/cm^2, preferably from 100 to 350 kg/cm^2, and a temperature of from 25° to 80°C, preferably from 30° to 60°C. At pressures lower than 50 kg/cm^2, the efficiency of extraction becomes poor, because the sol-

ubility of lipids is significantly decreased. On the contrary, at pressures higher than 500 kg/cm^2, extraction is not economical, because a greater cost is required for apparatus, although the solubility of lipids is increased. At temperatures lower than 25°C, the efficiency of extraction becomes poor, as in the case at lower pressures. On the contrary, at temperatures higher than 80°C, some problems of quality are caused by denaturation of the lipoprotein and deterioration of its functional properties.

The purpose of the step of separating the extracted lipids from the sub- or supercritical fluid can readily be attained by changing the pressure and temperature of the fluid to the ranges of from 1 to 200 kg/cm^2, preferably from 1 to 100 kg/cm^2, and from 10° to 100°C, preferably from 30° to 80°C, respectively, thereby reducing the solubility of the lipids. Also, a stepwise change in the pressure and temperature makes it possible to fractionate the lipoprotein-containing substance having a reduced lipid content.

The purpose of the separation step can also be attained by introducing the sub- or supercritical fluid dissolving the lipids into a vessel filled with an adsorbent, while maintaining the same pressure and temperature conditions as those employed for extraction, and removing the lipids contained in the fluid by adsorption. Examples of the adsorbent to be used for this purpose are activated charcoal, activated clay, silica gel, activated alumina, magnesium silicate and β-cyclodextrin. Depending upon the kind of an adsorbent to be used, it is also possible to attain the selective removal by adsorption only of the particular lipid ingredients, such as cholesterol and fatty acids, among the lipids extracted from the lipoprotein-containing substance.

In the foregoing, the sub- or supercritical fluid after the separation of the extracted lipids therefrom may be used again in the extraction step, while controlling or maintaining the pressure and temperature conditions for extraction. In this case, the fluid is repeatedly used in the extraction and separation steps without going into the discard, which is advantageous from the economical point of view.

Since the lipoprotein has a relatively stable structure in water as described above, the removal of lipids by extraction alone has an extremely low efficiency, even when it is conducted with a sub- or supercritical fluid. Therefore, a change in the structure of the lipoprotein by proteolytic enzymes or lipolytic enzymes is essential for the efficient removal of lipids by extraction.

In the process of the present invention, it is not necessary to use a dried substance as a raw material, as in the case of a conventional process, and it is possible to handle the raw material as it is in a liquid state. For this reason, a further economical process can be realized by conducting the enzyme treatment with proteolytic enzymes and/or lipolytio enzymes in the form of an immobilized enzyme or by employing a continuous contact system in the removal of lipids by extraction with a sub- or supercritical fluid.

In the case of such a continuous contact system, it is possible to use either the counter or parallel flow contact system. It is, however, necessary to make such a proper device that the efficient removal of lipids by extraction can be attained by, for example, charging an extraction column with packings to ensure a more proper contact time.

The lipoprotein-containing substances treated in the process of the present invention have reduced contents of neutral lipids and cholesterol at respective ratios of 30 to 90% in comparison with the starting raw material. These substances are used as a food material for preparing various kinds of food having reduced contents of neutral lipids and cholesterol. For example, they can be used for preparing various dishes such as scrambled eggs, egg soups, bacon and eggs, thick omelets, thin omelets, thick custard soups and coatings for fried food. The prepared dishes have substantially the same flavor as that of the dishes prepared from conventional eggs. Moreover, they can be used, instead of conventional eggs, as a raw material for various food products such as mayonnaise, egg custard, bread, rare cake, sponge cake, doughnuts, puff pastry, cookies, fluit pie, soft pie, sugar-coating confectionary, custard, biscuits, crackers, castella, cream puffs, custard pudding, milk pudding, bavarois, mousse, ice cream, eggnog, noodles and pasta. In these cases, almost no inferior flavor was found.

Furthermore, they can be used as a raw material of dried egg sheets and "Kinshi-tamago" (strips of thin omelet) to be prepared with a drum.

The following Examples further illustrate embodiments of the present invention in more detail.

Example 1

To 300 g of liquid egg yolk, 60 mg of Lipase M (manufactured by Amano Seiyaku Co., Ltd.) was added, and allowed to react thereon with stirring at 40°C for 2 hours. The decomposition ratio of triglycerides was 45%.

The liquid egg yolk thus treated was put into an extraction vessel of 1000 ml in volume, and carbon dioxide at a pressure of 230 kg/cm^2 and a temperature of 42°C was introduced thereinto for 2 hours for extraction of lipids, which were then separated in a separation vessel of 500 ml in volume under the conditions of 1 kg/cm^2 and 40°C. As the result, 51 g of extracts was obtained. After this operation of removing lipids by extraction, 240 g of the liquid egg yolk was recovered from the extraction vessel.

The resulting liquid egg yolk had such an appearance that the tone of its color became slightly thin, and other characteristics thereof were the same as those of egg yolk used as the raw material. The removal ratios of lipids and cholesterol were 61% and 68%, respectively.

Example 2

To 250 g of liquid egg yolk, 1.0 g of Protease A (manufactured by Amano Seiyaku Co., Ltd.) was added, and allowed to react thereon with stirring at 40°C for 3 hours. The degree of solubilization in TCA was 6.8%.

The liquid egg yolk thus treated was put into an extraction vessel of 1000 ml in volume, and carbon dioxide at a pressure of 300 kg/cm^2 and a temperature of 45°C was introduced thereinto for 2 hours for extraction of lipids, which were then separated in a separation vessel under the conditions of 50 kg/cm^2 and 45°C. As the result, 38 g of extracts was obtained. After this operation of removing lipids by extraction, 201 g of the liquid egg yolk was recovered from the extraction vessel.

The characteristics of the liquid egg yolk thus recovered were the same as those obtained in Example 1. The removal ratios of lipids and cholesterol were 55% and 59%, respectively.

Example 3

To 350 g of liquid egg yolk, 35 mg of Lipase F (manufactured by Amano Seiyaku Co., Ltd.) and 100 mg of Protease A (manufactured by Amano Seiyaku Co., Ltd.) were added, and allowed to react thereon with stirring at 40°C for 2 hours. The decomposition ratio of triglycerides and the degree of solubilization in TCA were 35% and 1.8%, respectively.

The liquid egg yolk thus treated was subjected to the removal of lipids by extraction under the same conditions as those employed in Example 2. As the result, 66 g of extracts was obtained and 273 g of the liquid egg yolk was recovered from the extraction vessel.

The characteristics of the liquid egg yolk thus recovered were the same as those obtained in Examples 1 and 2. The removal ratios of lipids and cholesterol were 71% and 77%, respectively.

Example 4

To 300 g of liquid whole egg, 30 mg of lipase "Saiken" (manufactured by Yakuruto Honsha Co., Ltd.) was added, and allowed to react thereon with stirring at 45°C for 5 hours. The decomposition ratio of triglycerides was 41%.

The liquid whole egg thus treated was put into an extraction vessel of 1000 ml in volume, and carbon dioxide at a pressure of 350 kg/cm^2 and a temperature of 38°C was introduced thereinto for 4 hours for extraction of lipids, which were then separated in a separation vessel of 500 ml in volume under the conditions of 10 kg/cm^2 and 40°C. As the result, 21 g of extracts was obtained. After this operation of removing lipids by extraction, 271 g of the liquid whole egg was recovered from the extraction vessel.

The liquid whole egg thus recovered had an appearance remaining substantially unchanged in comparison with that found before the treatment. The removal ratios of lipids and cholesterol were 60% and 62%, respectively.

Example 5

To 500 g of liquid egg yolk, 50 mg of Lipase M (manufactured by Amano Seiyaku Co., Ltd.) was added, and allowed to react thereon with stirring at 42°C for 2 hours. The decomposition ratio of triglycerides was 28%.

The liquid egg yolk thus treated was fed at a rate of 5 g/min. to the top of an extraction column of 40 mm in inner diameter and 1800 mm in length, which had been charged with glass beads of 5 mm in diameter, and carbon dioxide at a pressure of 250 kg/cm^2 and a temperature of 45°C was introduced at a flow rate of 400 N • l/min. into the column from its bottom for removal of lipids by extraction in a counter flow continuous contact system. The carbon dioxide from the column top was introduced into a separation vessel and the lipids contained therein were separated under the conditions of 1 kg/cm^2 and 35°C. As the result, 89 g of extracts was obtained and 392 g of the liquid egg yolk was recovered from the bottom of the extraction column.

The characteristics of the liquid egg yolk thus recovered had an appearance remaining substantially unchanged in comparison with those found before the treatment, similarly to the cases of Examples 1, 2, and 3. The removal ratios of lipids and cholesterol were 65% and 67%, respectively.

Example 6

The removal of lipids by extraction was conducted in the same manner as that described in Example 5, except that 40 mg of Lipase M (manufactured by Amino Seiyaku Co., Ltd.) and 100 mg of Protease S (manufactured by Amano Seiyaku Co., Ltd.) were added to 500 g of liquid egg yolk, and allowed to react thereon with stirring at 42°C for 2 hours. As the result, 387 g of the liquid egg yolk was recovered from the bottom of the extraction column, similarly to the case of Example 5. The removal ratio of lipids and cholesterol were 72% and 79%, respectively.

Example 7

The enzyme treatment and removal of lipids by extraction were conducted in the same manner as that described in Example 5, except that 500 g of liquid whole egg was used as a raw material. As the result, 458 g of the liquid whole egg was recovered from the bottom of the extraction column. The removal ratios of lipids and cholesterol were 60% and 61%, respectively.

Example 8

The enzyme treatment and removal of lipids by extraction were conducted in the same manner as that described in Example 5, except that 500 g of sugared egg yolk (obtained by addition of sucrose at a ratio of 20% to liquid egg yolk) was used as a raw material. As the result, 413 g of the sugared egg yolk was recovered from the bottom of the extraction column. The removal ratio of lipids and cholesterol were 70% and 74%, respectively.

Example 9

The enzyme treatment of Example 1 was applied to egg yolk and the removal of lipids by extraction was conducted in the same manner as that described in Example 1, except that carbon dioxide containing 3 wt% ethanol was used as an extraction solvent. The removal ratios of lipids and cholesterol were 88% and 86%, respectively.

Example 10

To 1 kg of porcine blood plasma, 0.4 mg of Lipoprotein Lipase (manufactured by Toyobo Co., Ltd.) was added, and allowed to react thereon with stirring at 45°C for 3 hours. The decomposition ratio of triglycerides was 42%. The porcine blood plasma thus treated was fed at a rate of 4 g/min. to the top of an extraction column of 40 mm in inner diameter and 1800 mm in length, which had been charged with Raschig rings (5 mm in outer diameter and 5 mm in height), and carbon dioxide at a pressure of 350 kg/cm^2 and a temperature of 42°C was introduced at a flow rate of 500 N • l/min. into the column from its bottom for removal of lipids by extraction in a counter flow continuous contact system. The carbon dioxide from the top of the column was introduced into a separation vessel, and the lipids contained therein were separated under the conditions of 55 kg/cm^2 and 40°C. As the result, 1.6 g of extracts was obtained, and 990 g of the porcine blood plasma was recovered from the bottom of the extraction column.

The total lipid content was 150 mg per 100 g of the porcine blood plasma thus recovered, and the removal ratio of total lipids was 56%. The porcine blood plasm thus recovered had almost no beastly odor in comparison with that found before the treatment.

Comparative Example 1

Without conducting enzyme treatment, 300 g of liquid egg yolk which was the same as that used in Example 1 was put into an extraction vessel of 1000 ml in volume, and the extraction was conducted with carbon dioxide under the same conditions as those employed in Example 1.

As the result, almost nothing was obtained as an extract, and it was, therefore, impossible to attain the removal of lipids containing cholesterol by extraction.

Comparative Example 2

Without conducting enzyme treatment, 1 kg of porcine blood plasma which was the same as that used in Example 11 was subjected to the removal of lipids by extraction under the same conditions as those employed in Example 11.

As the result, no extract was obtained and the porcine blood plasma which was recovered from the bottom of the extraction column remained having a strong beastly odor.

Example 11

To 300 g of liquid egg yolk which had been subjected to the enzyme treatment in the same manner as that described in Example 1, 100 g of medium-chain fatty acid triglycerides (manufactured by Nisshin Oil Mills Ltd.; ODO) was added, followed by mixing. The mixture was put into a vessel of 1000 ml in volume, and carbon dioxide at a pressure of 230 kg/cm^2 and a temperature of 45°C was introduced thereinto for 1 hour for extraction of lipids, which were then separated under the conditions of 50 kg/cm^2 and 30°C. As the result, 102 g of extracts was obtained. Although the lipid content in the liquid egg yolk after this treatment exhibited almost no change in comparison with that before the treatment, it was found that 66% of cholesterol was removed.

Example 12

Three hundred grams of liquid egg yolk which had been subjected to the enzyme treatment in the same manner as that described in Example 1 were put into an extraction vessel of 1000 ml in volume, and carbon dioxide at a pressure of 250 kg/cm^2 and a temperature of 45°C was introduced thereinto for extraction of lipids. The carbon dioxide after the extraction was allowed to pass through an adsorption vessel of 500 ml in volume, which had been connected next to the extraction vessel and filled with 100 g of activated clay, under the same pressure and temperature conditions as those described above. Thereafter, the removal of lipids by adsorption on the activated clay was conducted in a circulating system where the carbon dioxide was repeatedly allowed to pass through the extraction vessel and then through the adsorption vessel for 2 hours, while maintaining the same pressure and temperature conditions as those described above. As the result of this treatment, the removal ratios of lipids and cholesterol in the liquid egg yolk were 19% and 71%, respectively.

Example 13

Under the same conditions as those described in Example 1, about 10 kg of egg yolk was treated to prepare about 8 kg of liquid egg yolk having reduced contents of cholesterol and neutral lipids. The analytical data of egg yolk as the raw material and the treated liquid egg yolk of this example are shown in Table 1.

For the treated liquid egg yolk of this example, the removal ratios of cholesterol, lipids and neutral lipids were about 69%, about 55% and 80%, respectively, and the remaining ratio of phospholipids was 100%. To the treated liquid egg yolk of this example, water was added at a ratio of 20%, resulting in a liquid egg yolk (hereinafter referred to as prepared liquid egg yolk), which was used in the subsequent test.

Table 1

Items	Egg yolk as raw material	Treated liquid egg yolk
Water (wt%)	52.0	61.3
Proteins (wt%)	15.0	18.8
Lipids (wt%)		
Neutral lipids	20.3	5.1
Phospholipids	9.5	11.9
Carbohydrate (wt%)	0.5	0.6
Ash (wt%)	1.4	1.8
Cholesterol (wt%)	1.3	0.5

According to a conventional method, comparison between the egg yolk as the raw material and the prepared liquid egg yolk was made with respect to the capacity, activity, and stability of emulsification, and no difference was found therebetween.

The following food was prepared by using the prepared liquid egg yolk thus obtained.

Omelet

The prepared liquid egg yolk (200 g) was taken in a bowl, to which liquid egg white (550 g) and some amounts of sugar and salt were added, and the mixture was well mixed with a beater. The mixture was baked on a frying pan with a small amount salad oil to prepare an omelet (omelet A). Likewise, according to the same manner, an omelet (omelet B) was prepared, except that conventional eggs were used instead of the prepared liquid egg yolk. The organolepic evaluation was conducted by 20 panelists. The results are shown in Table 2. The figures in Table 2 are the numbers of panelists preferring the stated features of the respective omelettes.

Table 2

Evaluation	Omelet A	Omelet B
Better flavor	13	7
Better taste	11	9
Better body	5	15
Better chewing	8	12
Better overall evaluation	12	8

As seen from Table 2, although omelet A had pale yellow color in comparison with omelet B, the overall evaluation from the organolepic results was good. The cholesterol content, lipid content and caloric value of omelet A were reduced to about 31%, about 45% and about 68% of the corresponding one of omelet B, respectively.

Sponge cake

A mixture of egg white (500 g) and sugar (420 g) was well frothed in bowl A by agitating with a beater. Separately, a mixture of the prepared liquid egg yolk (700 g), sugar (400 g), and water (150 g) was well frothed in bowl B by agitating with a beater.

The contents of bowl B were put into bowl A, after which the mixture was well mixed and low gluten wheat flour (800 g) was added thereto, followed by slight mixing.

A small amount of vanilla essence was added thereto, and the mixture was baked in an oven to prepare a sponge cake (sponge cake A). Likewise, according to the same manner, a sponge cake (sponge cake B) was prepared, except that conventional liquid egg yolk was used instead of the prepared liquid egg yolk. The organolepic evaluation was conducted by 20 panelists. The results are shown in Table 3. The figures in Table 3 are the numbers of panelists preferring the stated features of the respective sponge cakes.

Table 3

Evaluation	Sponge cake A	Sponge cake B
Better flavor	14	6
Better taste	13	7
Better body	7	13
Better chewing	10	10
Better overall evaluation	13	7

The cholesterol content and lipid content in sponge cake A were reduced to about 31% and about 50% of the corresponding one of sponge cake B, respectively.

Custard pudding

A mixture of whole egg (200 g), the prepared liquid egg yolk (240 g), and sugar (360 g) was well stirred in a bowl, after which milk (1.2 kg) was added thereto while preventing bubbling. Further, vanilla essence (1 g) and a small amount of rum were added thereto, and the mixture was dispensed as appropriate portions into 300 ml cups. These cups were heated with steam in an oven at 150° to 160°C for 40 minutes, followed by cooling, to prepare a custard pudding (pudding A).

Likewise, according to the same manner, a custard pudding (pudding B) was prepared, except that conventional liquid egg yolk was used instead of the prepared liquid egg yolk. The organolepic evaluation was conducted by 20 panelists. The results are shown in Table 4. The figures in Table 4 are the numbers of panelists preferring the stated fea-

tures of the custard pudding.

Table 4

Evaluation	Custard pudding A	Custard pudding B
Better flavor	13	7
Better taste	12	8
Better body	9	11
Better chewing	9	11
Better overall evaluation	11	9

The cholesterol content and neutral lipid content in custard pudding A were reduced to about 48.3% and about 56.8% of the corresponding one of custard pudding B, respectively.

Mayonnaise

According to the formulation as shown in Table 5, the prepared liquid egg yolk, sugar, salt, powdered mustard, pepper, paprika, and one half the total amount of vinegar were mixed in a stainless steel pot to form a uniform mixture which was then put into a mixer. The mixture was agitated by a mixer with addition of salad oil and the remaining vinegar thereto, resulting in an emulsified mixture. Further, the contents of the mixer were put into to a stainless steel vessel, and treated with a colloid mill for several seconds to prepare a mayonnaise (mayonnaise A).

Likewise, according to the same manner, a mayonnaise (mayonnaise B) was prepared, except that conventional egg yolk was used instead of the prepared liquid egg yolk. The formulation of mayonnaise B is also shown in Table 5. The organolepic evaluation was conducted by 20 panelists. The results are shown in Table 6. The figures in Table 6 are the numbers of panelists preferring the stated features of the mayonnaise.

Table 5

Ingredients	Mayonnaise	
	A (wt%)	B (wt%)
Conventional egg yolk	-	18.0
Treated liquid egg yolk	18.0	-
Vinegar	9.4	9.4
Sugar	2.2	2.2
Salt	1.3	1.3
Powdered mustard	0.9	0.9
Pepper	0.1	0.1
Paprika	0.1	0.1
Salad oil	68.0	68.0

Table 6

Items	Mayonnaise A	Mayonnaise B
Better flavor	15	5
Better taste	13	7
Better body	8	12
Better smoothness	11	9
Better overall evaluation	10	10

As shown in Table 6, no difference in overall evaluation was found between mayonnaises A and B. When both mayonnaises were allowed to stand at 50°C for 10 and 20 days, no difference in appearance was found between mayonnaises A and B. The cholesterol content in mayonnaise A were about 31% of that of mayonnaise B.

Claims

1. A process for producing a lipoprotein-containing substance having a reduced lipid content, which comprises the steps of

   (1) treating a lipoprotein-containing substance with at least one enzyme selected from proteolytic enzymes, lipases and lipoprotein lipases;
   (2) thereafter, bringing the enzyme treated substance into contact with a sub- or supercritical fluid to extract lipid therefrom; and
   (3) separating the extracted lipid from the fluid.

2. A process according to claim 1, wherein the lipoprotein-containing substance is liquid egg yolk, liquid whole egg, blood plasma or milk.

3. A process according to claim 1 or 2, wherein the degree of solubilization in 0.22 M trichloroacetic acid of proteins in the substance after the treatment with proteolytic enzymes is from 1.5% to 80%.

4. A process according to claim 1, 2 or 3, wherein the lipoprotein-containing substance is treated with a lipase or lipoprotein lipase and then decomposition ratio of lipids in the substance after the said treatment is from 1% to 80%.

5. A process according to any preceding claim, wherein the extraction of lipids is conducted with a mixture of the sub- or supercritical fluid and a co-solvent.

6. A process according to claim 5, wherein the co-solvent is selected from at least one of ethanol, methanol, acetone, hexane, palm kernel oil, coconut oil and medium-chain fatty acid triglycerides.

7. A process according to any preceding claim, wherein the lipid is selected from at least one of monoglycerides, diglycerides, triglycerides, fatty acids and cholesterol.

8. A process according to claim 1, wherein the substance treated with the enzyme is mixed with a co-solvent, after which the lipid is extracted with the sub- or supercritical fluid.

9. A process according to claim 8, wherein the co-solvent is selected from at least one of palm kernel oil, coconut oil and medium-chain fatty acid triglycerides.

10. A process according to claim 8 or 9, wherein the lipid is cholesterol or a fatty acid.

11. A process according to any preceding claim, wherein the extraction of lipids is conducted at a pressure of from 50 to 500 kg/cm^2 and a temperature of from 25° to 80°C.

12. A process according to any preceding claim, wherein the substance treated with the enzyme is brought into contact

with the sub- or supercritical fluid in a counter or parallel flow continuous contact system for extraction of lipids.

13. A process according to any preceding claim, wherein the lipid extracted from the lipoprotein-containing substance is separated from the sub-or supercritical fluid at a pressure of from 1 to 200 kg/cm^2 and a temperature of from 10° to 100°C.

14. A process according to any preceding claim, wherein the lipid extracted from the lipoprotein-containing substance is separated from the sub-or supercritical fluid by adsorbing the lipid on an adsorbent.

15. A process according to claim 14, wherein the adsorbent is selected from activated charcoal, activated clay, silica gel, activated alumina, magnesium silicate and β-cyclodextrin.

16. A process according to any preceding claim, wherein the sub- or supercritical fluid is carbon dioxide.

Patentansprüche

1. Verfahren zur Herstellung einer lipoproteinhaltigen Substanz mit reduziertem Lipidgehalt, das folgende Schritte umfasst:

   (1) Behandlung einer lipoproteinhaltigen Substanz mit mindestens einem Enzym, ausgewählt aus proteolytischen Enzymen, Lipasen und Lipoproteinlipasen;

   (2) anschliessendes Kontaktieren der enzymbehandelten Substanz mit einem sub- oder superkritischen Fluid, wodurch Lipide daraus extrahiert werden; und

   (3) Abtrennen des extrahierten Lipids von dem Fluid.

2. Verfahren gemäss Anspruch 1, worin die lipoproteinhaltige Substanz flüssiges Eigelb, flüssiges Vollei, Blutplasma oder Milch ist.

3. Verfahren gemäss Anspruch 1 oder 2, worin der Löslichkeitsgrad der Proteine in der Substanz nach der Behandlung mit proteolytischen Enzymen in 0,22 M Trichloressigsäure im Bereich von 1,5 bis 80 % liegt.

4. Verfahren gemäss Anspruch 1, 2 oder 3, worin die lipoproteinhaltige Substanz mit einer Lipase oder einer Lipoproteinlipase behandelt wird, und das Zersetzungsverhältnis der Lipide in der Substanz nach der Behandlung 1 bis 80 % beträgt.

5. Verfahren gemäss mindestens einem der vorhergehenden Ansprüche, worin die Extraktion der Lipide mit einer Mischung des sub- oder superkritischen Fluids und einem Co-Lösungsmittel durchgeführt wird.

6. Verfahren gemäss Anspruch 5, worin das Co-Lösungsmittel mindestens eines ist, ausgewählt aus Ethanol, Methanol, Aceton, Hexan, Palmkernöl, Kokosnussöl und mittelkettigen Fettsäuretriglyceriden.

7. Verfahren gemäss mindestens einem der vorhergehenden Ansprüche, worin das Lipid mindestens eines ist, ausgewählt aus Monoglyceriden, Diglyceriden, Triglyceriden, Fettsäuren und Cholesterin.

8. Verfahren gemäss Anspruch 1, worin die mit dem Enzym behandelte Substanz mit einem Co-Lösungsmittel gemischt wird, wonach das Lipid mit dem sub- oder superkritischen Fluid extrahiert wird.

9. Verfahren gemäss Anspruch 8, worin das Co-Lösungsmittel mindestens eines ist, ausgewählt aus Palmkernöl, Kokosnussöl und mittelkettigen Fettsäuretriglyceriden.

10. Verfahren gemäss Anspruch 8 oder 9, worin das Lipid Cholesterin oder eine Fettsäure ist.

11. Verfahren gemäss mindestens einem der vorhergehenden Ansprüche, worin die Extraktion der Lipide bei einem Druck von 50 bis 500 kg/cm^2 und einer Temperatur von 25 bis 80°C durchgeführt wird.

12. Verfahren gemäss mindestens einem der vorhergehenden Ansprüche, worin die mit einem Enzym behandelte Substanz mit dem sub- oder superkritischen Fluid in einem kontinuierlichen Gegen- oder Parallelstrom-Kontaktsy-

stem zur Extraktion von Lipiden kontaktiert wird.

13. Verfahren gemäss mindestens einem der vorhergehenden Ansprüche, worin das aus der lipoproteinhaltigen Substanz extrahierte Lipid bei einem Druck von 1 bis 200 kg/cm^2 und einer Temperatur von 10 bis 100°C von dem sub- oder superkritischen Fluid abgetrennt wird.

14. Verfahren gemäss mindestens einem der vorhergehenden Ansprüche, worin das aus der lipoproteinhaltigen Substanz extrahierte Lipid durch Adsorption des Lipids auf einem Adsorptionsmittel von dem sub- oder superkritischen Fluid abgetrennt wird.

15. Verfahren gemäss Anspruch 14, worin das Adsorptionsmittel ausgewählt ist aus Aktivkohle, aktiviertem Ton, Silicagel, aktiviertem Aluminiumoxid, Magnesiumsilicat und β-Cyclodextrin.

16. Verfahren gemäss mindestens einem der vorhergehenden Ansprüche, worin das sub- oder superkritische Fluid Kohlendioxid ist.

Revendications

1. Procédé de production d'une substance contenant des lipoprotéines et ayant une teneur réduite en lipides, qui comprend les étapes suivantes :

   (1) le traitement d'une substance contenant des lipoprotéines avec au moins une enzyme choisie parmi les enzymes protéolytiques, les lipases et les lipoprotéines-lipases ;
   (2) ensuite, la mise en contact de la substance traitée par l'enzyme avec un fluide sous- ou super-critique pour en extraire les lipides; et
   (3) la séparation des lipides extraits du fluide.

2. Procédé selon la revendication 1, dans lequel la substance contenant des lipoprotéines est du jaune d'oeuf liquide, de l'oeuf entier liquide, du plasma sanguin ou du lait.

3. Procédé selon l'une des revendications 1 ou 2, dans lequel le degré de solubilisation dans de l'acide trichloroacétique 0,22 M des protéines contenues dans la substance après traitement avec les enzymes protéolytiques est de 1,5 % à 80 %.

4. Procédé selon l'une des revendications 1, 2 ou 3, dans lequel la substance contenant des lipoprotéines est traitée avec une lipase ou une lipoprotéine-lipase et le rapport de décomposition des lipides contenus dans la substance après ledit traitement est de 1 % à 80%.

5. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'extraction des lipides est conduite avec un mélange d'un fluide sous- ou super-critique et d'un co-solvant.

6. Procédé selon la revendication 5, dans lequel le co-solvant est au moins un choisi parmi l'éthanol, le méthanol, l'acétone l'hexane, l'huile de noix de palme, l'huile de noix de coco et les triglycérides d'acide gras à chaîne intermédiaire.

7. Procédé selon l'une quelconque des revendications précédentes, dans lequel le lipide est au moins un choisi parmi les monoglycérides, diglycérides, triglycérides, acides gras et cholestérol.

8. Procédé selon la revendication 1, dans lequel la substance traitée avec l'enzyme est mélangée avec un co-solvant, à la suite de quoi le lipide est extrait avec le fluide sous- ou super-critique.

9. Procédé selon la revendication 8, dans lequel le co-solvant est au moins un choisi parmi l'huile de noix de palme, l'huile de noix de coco et les triglycérides d'acides gras à chaîne intermédiaire.

10. Procédé selon la revendication 8 ou 9, dans lequel le lipide est le cholestérol ou un acide gras.

11. Procédé selon l'une quelconque des revendications précédentes, dans lequel l'extraction des lipides est menée à une pression de 50 à 500 kg/cm^2 et une température de 25° à 80°C.

12. Procédé selon l'une quelconque des revendications précédentes, dans lequel la substance traitée avec l'enzyme est mise en contact avec le fluide sous- ou super-critique dans un système de contact à contrecourant ou courant parallèle continu pour l'extraction des lipides.

13. Procédé selon l'une quelconque des revendications précédentes, dans lequel le lipide extrait de la substance contenant des lipoprotéines est séparé du fluide sous- ou super-critique à une pression de 1 à 200 kg/cm^2 et une température de 10° à 100°C.

14. Procédé selon l'une quelconque des revendications précédentes, dans lequel le lipide extrait de la substance contenant des lipoprotéines est séparé du fluide sous- ou super-critique par adsorption du lipide sur un adsorbant.

15. Procédé selon la revendication 14, dans lequel l'adsorbant est choisi parmi le charbon activé, l'argile activée, un gel de silice, l'alumine activée, le silicate de magnésium et une β-cyclodextrine.

16. Procédé selon l'une quelconque des revendications précédentes, dans lequel le fluide sous- ou super-critique est du dioxyde de carbone.